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Programme for Life Extension and Widespread Fatigue Damage Evaluation to Ensure Continued Structural Integrity of Airbus Large Transport Category Airplanes

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Keywords : ageing aircraft, life extension, widespread fatigue damage, Monte Carlo Simulation

Abstract

The Airworthiness Assurance Working Group (AAWG) has been charted by FAA to enhance and develop rules for continued structural integrity of large transport category airplanes. The subgroup AAWG – RWG (Rule Writing Group) has completed a draft proposal for enhancement of AC91-56 and the introduction of operational rules of aircraft operated under 14 CFR Parts 91, 121, 125, 129 and 135.

The Airbus activities to meet the new regulations are in progress for the Airbus types A300B2, A300B4-100, A300B4-200 and A300B4-600. This paper describes details of tests, analysis and procedures to meet the new requirements and recommendations. The presentation discusses especially the activities for the pressurized fuselage, which is mainly under the responsibility of Airbus Deutschland GmbH.

The Airbus Life Extension activities include a general review of the fatigue and damage tolerance analysis prepared for type certification, interpretation of full scale fatigue test findings, tear down results and SB review with respect to extended service goals.

Special emphasis will be given to the investigation and analysis of Widespread Fatigue Damage (WFD). Compliance must be ensured with the new requirements, which concern the need to limit the validity of the current structural maintenance programme and the need to impose operational requirements that mandate a structural maintenance programme to prevent WFD in the fleet. The WFD evaluation of the fuselage will be performed using a new analysis tool developed in a European research programme and extended and validated by Airbus Deutschland GmbH within the last years. The new analysis tool is verified by extensive coupon and panel testing comprising fatigue, crack growth and residual strength tests for the major areas potentially susceptible to WFD.

Another important topic of the life extension activities is the prevention of corrosion in the ageing fleet. Therefore a Corrosion Prevention and Control Programme (CPCP) was established which is reviewed periodically.

In addition the structure of a retired high-time A300 is investigated in detail to support the life extension activities. Tear down investigation of critical areas and areas potentially susceptible to WFD are performed. Several structural parts, e.g. large panels are cut out of the airframe and tested for fatigue, crack growth and residual strength capabilities. In addition material properties, i.e. crack growth data and fracture toughness data will be determined for the aged structure and compared to more recent values.

Paper presented at the RTO AVT Specialists' Meeting on "Life Management Techniques for Ageing Air Vehicles", held in Manchester, United Kingdom, 8-11 October 2001, and published in RTO-MP-079(II).

Status of Airbus Fleet

The A300 aircraft was the first of the Airbus types and approximately 500 aircraft are currently in service. This number includes an increasing number of older aircraft converted from passenger to freighter configuration. The A300 entered airline operation in May 1974 and production of the A300B4-600 variant continues today, however, some early models of the A300 are now approaching their Design Service Goal (DSG), i.e. *the number of flight cycles or flight hours during which the principal structure is expected to be reasonably free from significant cracking.*
As can be seen from Figure 1 the Airbus fleets are still relatively young with the majority of the airplanes below 50 percent of their DSG [1]. No Airbus aircraft has reached its DSG up to now.
However, in May 1999 26 A300 as well as 15 A300-600 aircraft had exceeded 75 percent of their DSG. The high-time A300 B2/B4 and A300-600 aircraft will reach their DSGs within the next few years. In 1997 a forecast of the fleet status was made for planning of the Airbus life extension activities. Figure 2 shows the development of the A300 variants for the years 2001 to 2005. Especially a considerable number of A300B4-600 aircraft will reach the DSG very soon. Consequently, life extension activities including widespread fatigue damage evaluation are needed.

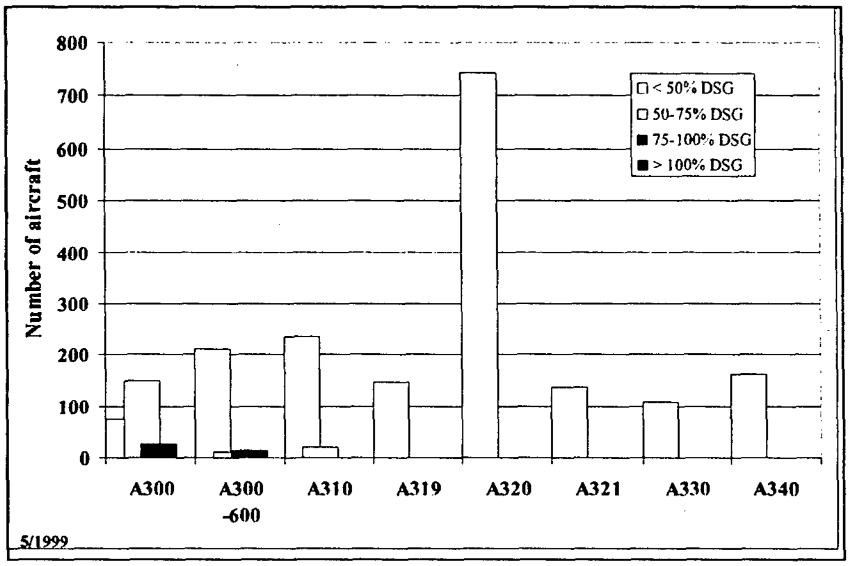

Figure 1 : Age of Airbus A300 Fleet

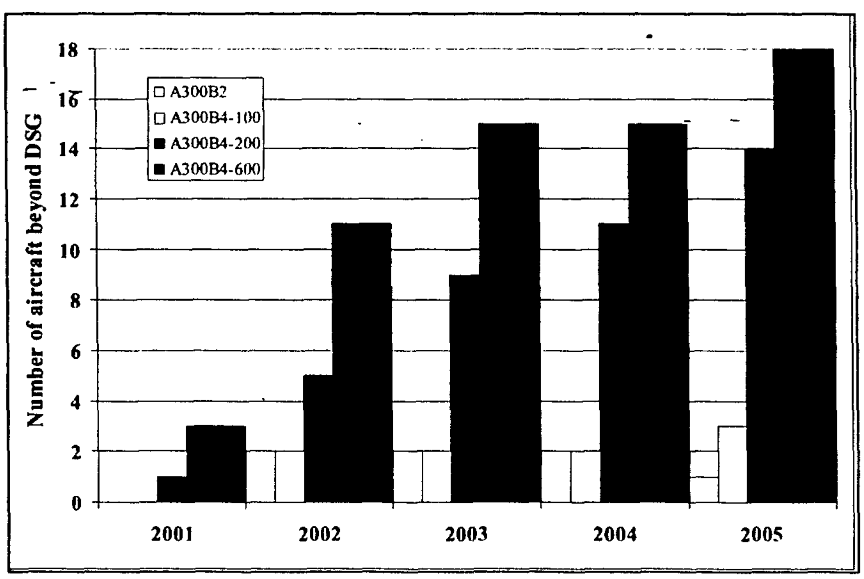

Figure 2 : Predicted Development of Airbus A300 Fleet

New Design Service Goals

The original DSG is generally established at the time of type certification and is not intended to limit the life of the structure, or to define the point at which the aircraft can not continue its operation. In the case of the A300 aircraft, operators have requested continued operation beyond the DSG, and the issue of an extension of the service life is now being addressed. In close cooperation with the operators Airbus has defined new, extended service goals (ESG) for the various A300 models. The table below summarizes the new ESGs :

A/C Type	Design Service Goal [FC]	Extended Service Goal [FC]	Increase [%]
A300 B2	48 000	60 000	25
A300 B4-100	40 000	57 000	42.5
A300 B4-200	34 000	42 500/57 000	25/67.6
A300 B4-600	30 000	42 500	42

General Approach

To reach the above new ESGs Airbus Industry has launched a Full Life Extension Programme for the A300 aircraft. In order to justify a further period of operation up to the new ESG, it is necessary to review service experience and re-assess the existing inspection programmes. This may lead to a modification of the maintenance strategy, including the inspection of additional items or an increased level of surveillance in some areas.

The following activities are performed under the A300 Full Life Extension.

- Fatigue and damage tolerance analysis of the original structure and modifications including :
    - Detailed identification of the concerned area
    - Review of Full Scale Fatigue Test (A300, A310) and in-service experiences
    - Loads comparison for all variants
    - Review of former fatigue justifications
    - New calculations
    - Review of Service Bulletins and current inspection programme
- Widespread Fatigue Damage Analysis
- Update of all inspection programmes incl. MRB, SSIP and the definition of new programmes
- Definitions of modifications or replacement of structure including embodiment threshold

In addition to these activities all repairs and in-service problems that were monitored by the operator must be considered in the ESG analysis. Therefore a complete review of all repairs, in-service problems and of the Structural Repair Manual (SRM) is required.

The activities are especially tuned to the pressurized fuselage, which is mainly under the responsibility of Airbus Deutschland GmbH. Additionally some areas of the Vertical and Horizontal Tailplane are investigated.

All activities are supported by comprehensive WFD and local damage testing and tear down investigation of a retired airframe.

Furthermore, the life extension activities including WFD evaluation are significantly supported by the results of the full scale fatigue tests. The A300 aircraft was tested in a multi-section test for at least two lifetimes. Figure 3 shows the four A300 FSFT specimens together with the number of simulated flights.

For the assessment of areas susceptible to local damage only a conventional fatigue and damage tolerance analysis may be used. However, for the analysis of WFD susceptible areas a new approach was developed.

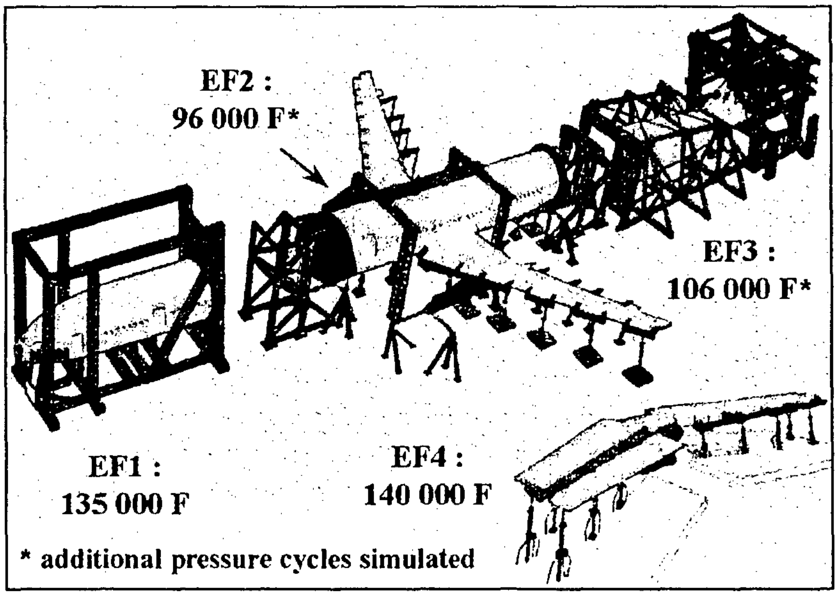

Figure 3 : A300 Full Scale Fatigue Test

Conventional Local Damage Evaluation

The evaluation of all structural items potentially susceptible to local damage will be performed according to the philosophy outlined Figure 4. The evaluation is based on analysis supported by comprehensive testing. This kind of structure is fully protected by the existing maintenance programme up to the DSG. Areas where fatigue damages occurred during the FSFT are covered by inspection and/or modification or by production improvements.

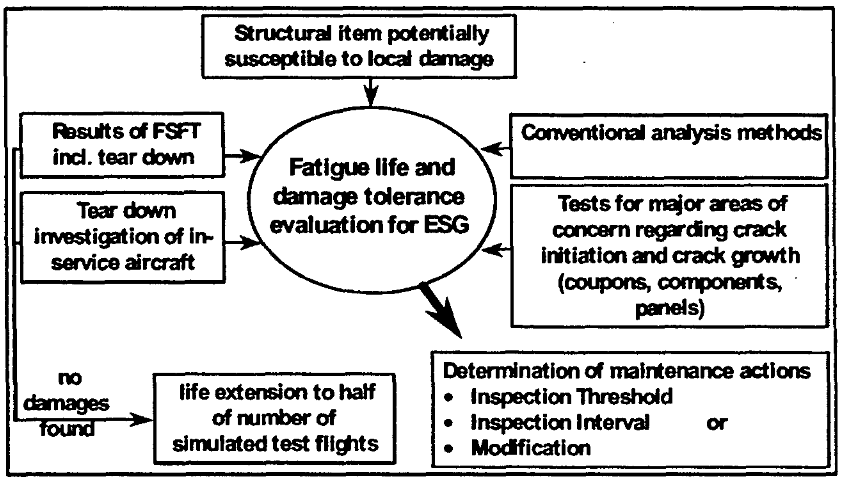

Figure 4 : Approach used for the evaluation of local damage

For life extension the results of the FSFTs are evaluated again in order to define additional areas which need to be assessed. This assessment is done for all areas by fatigue life and damage tolerance analysis using conventional state of the art analysis tools. For some specific areas this analysis is again supported by testing of coupons, components or panels.

A more simple justification is possible for all areas where no damages occurred neither during FSFT nor during tear down investigations. The life of these areas may be extended up to half of the number of flights simulated in test, adjusted by the relevant flight mission data.

Widespread Fatigue Damage Evaluation

Since fatigue crack initiation becomes more likely with extended service, the evaluation of structural items potentially susceptible to WFD requires a more complex analysis.

With extended operation there is an increased probability of Multiple Site Damage (MSD), *i.e. the simultaneous presence of multiple fatigue cracks in the same structural element*, or Multiple Element Damage (MED), *i.e. the simultaneous presence of multiple fatigue cracks in similar adjacent structural elements*. MSD and MED can seriously degrade the damage tolerance capability, i.e. the residual strength of the structure, and may develop into Widespread Fatigue Damage (WFD), which is defined as the point where *the structure is no longer able to meet the required level of residual strength*. Thus, the prevention of WFD is an important issue to the continued safe operation of ageing aircraft, and special WFD analysis methods have been developed.

Following discussions between the manufacturers, aircraft operators and regulatory authorities undertaken by the Ageing Aircraft Working Group (AAWG), a draft proposal for enhancement of AC91-56 and the introduction of operational rules for aircraft operated under 14 CFR Parts 91, 121, 125, 129 and 135 was issued [2]. Compliance must be ensured with the new requirements, which concern the need to limit the validity of the current structural maintenance programme and the need to impose operational requirements that mandate a structural maintenance programme to prevent WFD in the fleet.

The new rule requires the introduction of specific detailed inspections for MSD/MED, and the declaration of an '*Inspection Start Point (ISP)*', where special WFD inspections must be started, and an operational limit, known as the '*Structural Modification Point (SMP)*', beyond which a structural item may not be used without modification because of the increased risk of WFD. The SMP is derived from the average expected behavior. Beyond this point the airplane may not be operated without further evaluation and modification. The SMP is established so, that operation up to the point provides equivalent protection to that of a two lifetime fatigue test.

For structure where the MSD/MED situation is reliably detectable before it becomes critical a so-called monitoring period may be defined and applied before other means have to be taken. The monitoring period is the period of time between ISP and SMP. Repeat inspection intervals are established based on the length of time from detectable fatigue cracks to the average WFD divided by a factor.

Consequently, for each structural item potentially susceptible to WFD the analysis method must provide both the ISP and the SMP, as well as the interval of repeat inspections during the monitoring period. An example is shown in Figure 5, where MSD inspections start at 36000 FC with an repeat inspection interval of aprox. 7000 FC until the SMP is reached at 54000 FC. These values were derived according to the recommendations provided by the AAWG, which state that SMP and ISP are determined by applying a factor of 2 and 3 on the WFD Average Behaviour, respectively.

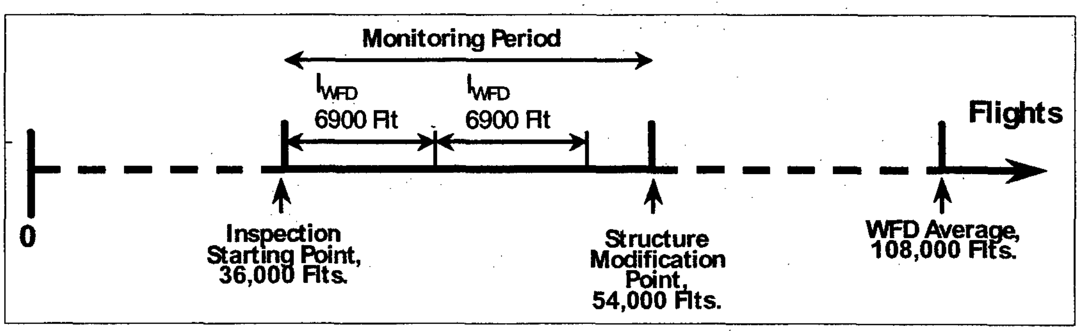

Figure 5 : Example of Determination of Inspection Programme

The WFD phenomenon is commonly associated with longitudinal or circumferential fuselage lap joints, such as in the *Aloha Airlines* Boeing 737 accident of April 1989, in which widespread fatigue and corrosion damage in a high-time aircraft led to an in-flight structural failure and explosive decompression [3]. Although initially independent, the development of these cracks may eventually lead to interaction and link-up of damage sites, and the possibility of structural failure.

The structural items within the fuselage structure of a commercial large transport category aircraft that are potentially susceptible to MSD/MED have been identified by the AAWG [2]. These locations are summarized as follows:

- Longitudinal Skin Joints, Frames and Tear Straps (MSD/MED)
- Circumferential Joints and Stringers (MSD/MED)
- Lap Joints with Milled, Chem-milled or Bonded Radius (MSD)
- Fuselage Frames (MED)
- Stringer to Frame Attachments (MED)
- Shear Clip End Fasteners on Shear Tied Fuselage Frames (MSD/MED)
- Aft Pressure Dome Outer Ring and Dome Web Splices (MSD/MED)
- Skin Splice at Aft Pressure Bulkhead (MSD)
- Abrupt Changes in Web or Skin Thickness Pressurized or Unpressurized Structure (MSD/MED)
- Window Surround Structure (MSD/MED)
- Latches and Hinges of Non-plug Doors (MSD/MED)
- Skin at Runout of Large Doubler (MSD) Fuselage, Wing or Empennage

In the case of the Airbus A300, a number of specific structural features may be identified that correspond to the generic items in the above list. These locations must be considered during the WFD assessment required to justify extended service of the aircraft.

The general approach for the WFD assessment used by Airbus Deutschland GmbH is presented in Figure 6. As for the local damages the results of the FSFTs including tear down are taken into account, but furthermore specific analysis methods are necessary to determine the WFD parameters.
Additionally, a large testing programme was launched to investigate the behaviour of structural items in the presence of MSD.
Both the WFD analysis tool and the WFD Testing Programme are described in the following chapters.

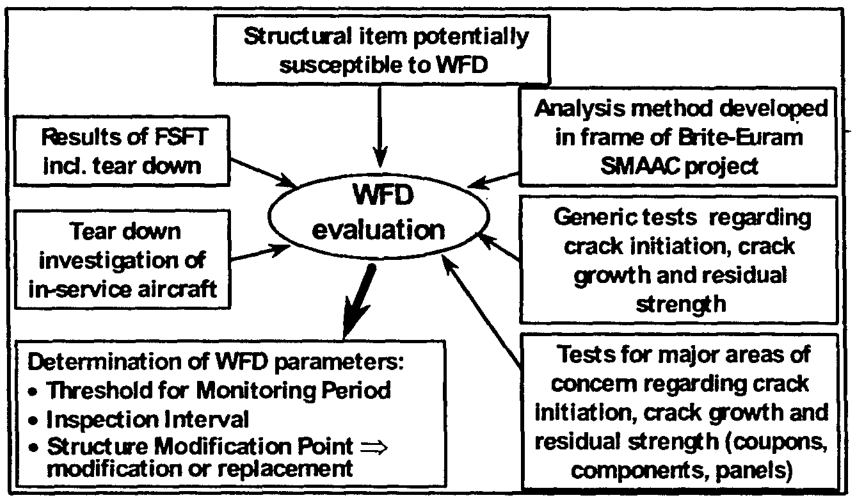

Figure 6 : Approach used for WFD Evaluation

Widespread Fatigue Damage Analysis

Effect of MSD

The cause of the *Aloha Airlines* accident was assigned to the presence of small cracks at adjacent fastener holes, MSD, in a skin lap splice leading to inflight structural failure of the upper part of the forward fuselage [3]. Therefore, the main issue of the aging aircraft fleet is the occurrence of multiple

damages at adjacent locations (MSD, MED) which influence each other. This so-called 'interaction of cracks' leads to higher stress intensity factors at the crack tips and consequently to higher crack propagation rates.
The effect of MSD is shown in **Figure 7**. In the presence of MSD adjacent to a lead crack the residual strength is reduced drastically. The drop of the residual strength from the capability of the intact structure to the capability required to withstand the design loads occurs in a much shorter time compared to the case of a local damage. Furthermore the crack growth for a MSD scenario is increased compared with the single crack. Together with the reduced critical crack length, this results in a significantly reduced crack growth period between the detectable and critical situation. The diagram also acknowledges the fact that while the MSD crack growth and residual strength degradation occurs in a more rapid sense, it is also expected to occur later in the life of a structural detail. This very rapid decrease of the residual strength in MSD situations due to crack interaction and accelerated crack growth must be taken into account during each analysis process.

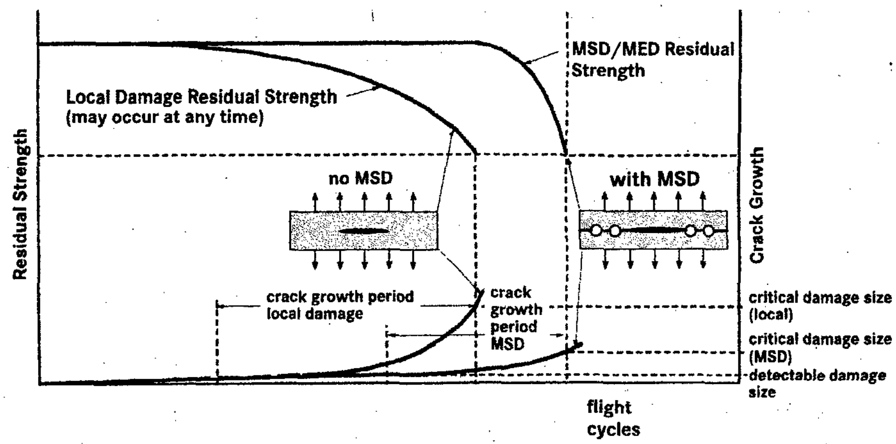

Figure 7 : Effect of MSD

Analysis Method

The analysis method for WFD evaluation was mainly developed by of the European research project 'Structural maintenance of Ageing Aircraft' (SMAAC) [4], partly founded by the European Commission. Significant additional effort was undertaken at Airbus to derive and validate an engineering tool for the Airbus structure to be evaluated. The development of this engineering tool was supported by extensive testing, which is described in the next chapter.
The main objective of the method is to estimate the development and evolution of MSD/MED in an aircraft structure. This information would permit the definition of an inspection programme for MSD/MED cracking. At a fundamental level, the methodology attempts to model both the initiation of multiple cracks at repetitive features within a structure susceptible to MSD/MED (e.g. a fastener hole in a lap joint), and the subsequent growth of those cracks after initiation. In the approach used by Airbus this is done by means of a Monte-Carlo simulation, where multiple initial crack scenarios are randomly generated and for each scenario subsequent crack propagation and failure is calculated (Figure 8). The method is summarized as follows [4]:

- The first step is the definition of the initial damage scenario. Each potential crack location (e.g. two sides per fastener hole in a lap splice) is allocated a crack initiation time. The initiation time is determined by randomly drawing a "life" from an overall log-normal distribution of fatigue lives for simple coupons.
- The propagation of each initiated crack is calculated through the techniques of linear elastic fracture mechanics. The major parameter within each crack propagation calculation is the stress intensity factor at the crack tip. Due to the nature of the MSD problem, within this model a number of solutions account for the interaction of cracks with other cracks. Plasticity effects are accounted for by considering Irwin's plastic zone in front of each crack tip. There are different ways of calculating the stress intensity factor, for example FEM, BEM, complex stress functions or compounding. Since a very important feature within a Monte-Carlo Simulation is the

computer time consumption, this model uses the compounding method, because it combines reasonable accuracy with very short calculation time compared to other methods.

- A damage accumulation procedure accounts for the effect of stress redistribution on the initiation of additional cracks. This stress redistribution is a consequence of the occurrence and growth of cracks Three main effects are considered here: the increase of net stress, the stress increase at the uncracked side of a cracked hole and the stress increase at an uncracked hole adjacent to a cracked hole. The increased accumulation of damage due to these effects leads to earlier crack initiation at the considered locations. This type of damage accumulation ensures a realistic simulation of the MSD behaviour in WFD susceptible components.
- Damage accumulation and crack propagation stop at failure. Three different failure criteria may be applied : reaching a critical stress intensity factor, net section yielding or exceeding a given lead crack size. A reliable estimate of the residual strength of a component in the presence of MSD is needed to complete the WFD analysis. Therefore, a R-curve analysis procedure has been implemented, which accounts for crack interaction. In this procedure each crack tip of a simulated crack scenario is investigated for unstable crack extension

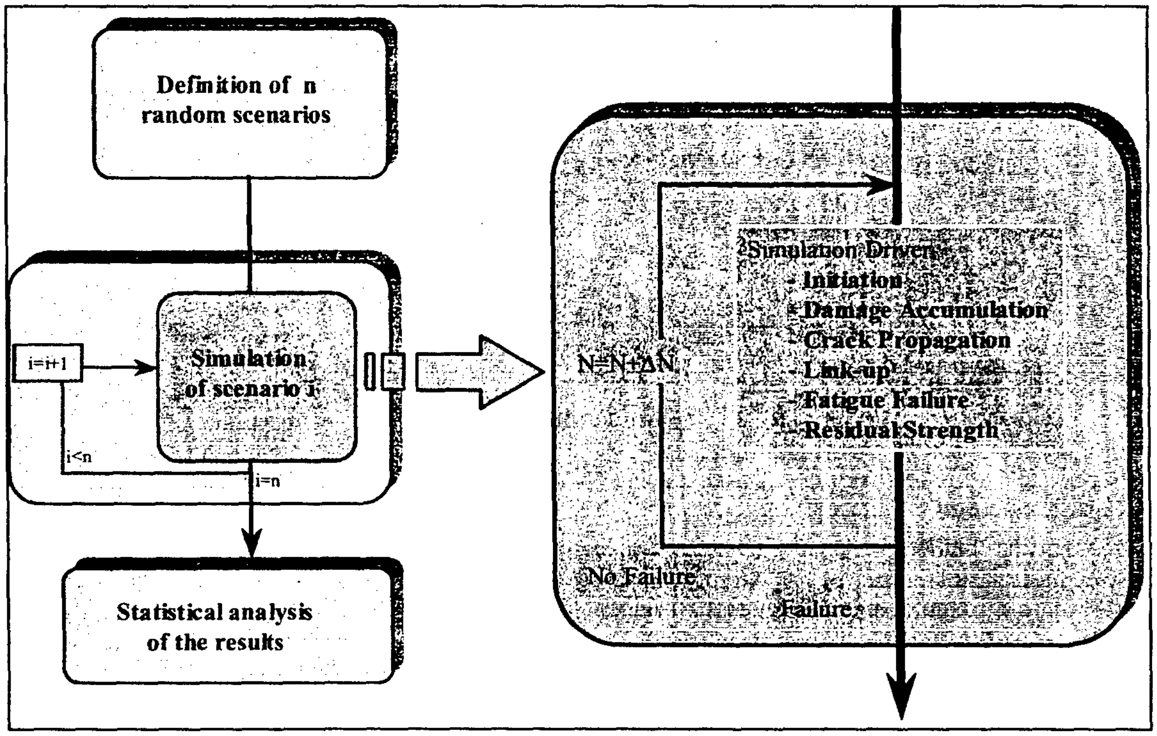

Figure 8 : Flow Chart of WFD Analysis Method

These stages form a single Monte-Carlo iteration (Figure 9) and are repeated many times to form a complete Monte-Carlo simulation of the structural item under investigation. The results of n iterations are evaluated statistically to obtain probability distributions, mean values and standard deviation for the Time to Initiation (left/blue curve in Figure 10), the Time to Detectable (mid/green curve in Figure 10)and the WFD Average Behaviour / mean of Time to Failure/Endurance (right/red curve in Figure 10).

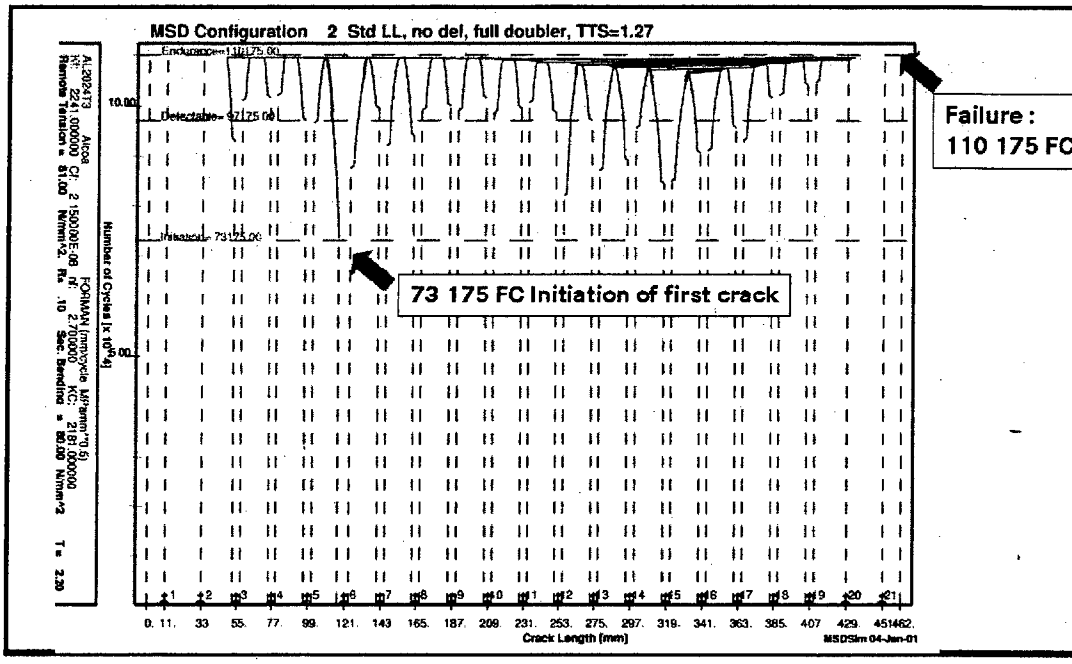

Figure 9 : Result of a single Monte Carlo Iteration : shown is the evolution of a scenario in a lap joint, i.e. the position of crack tips/holes against the number of cycles

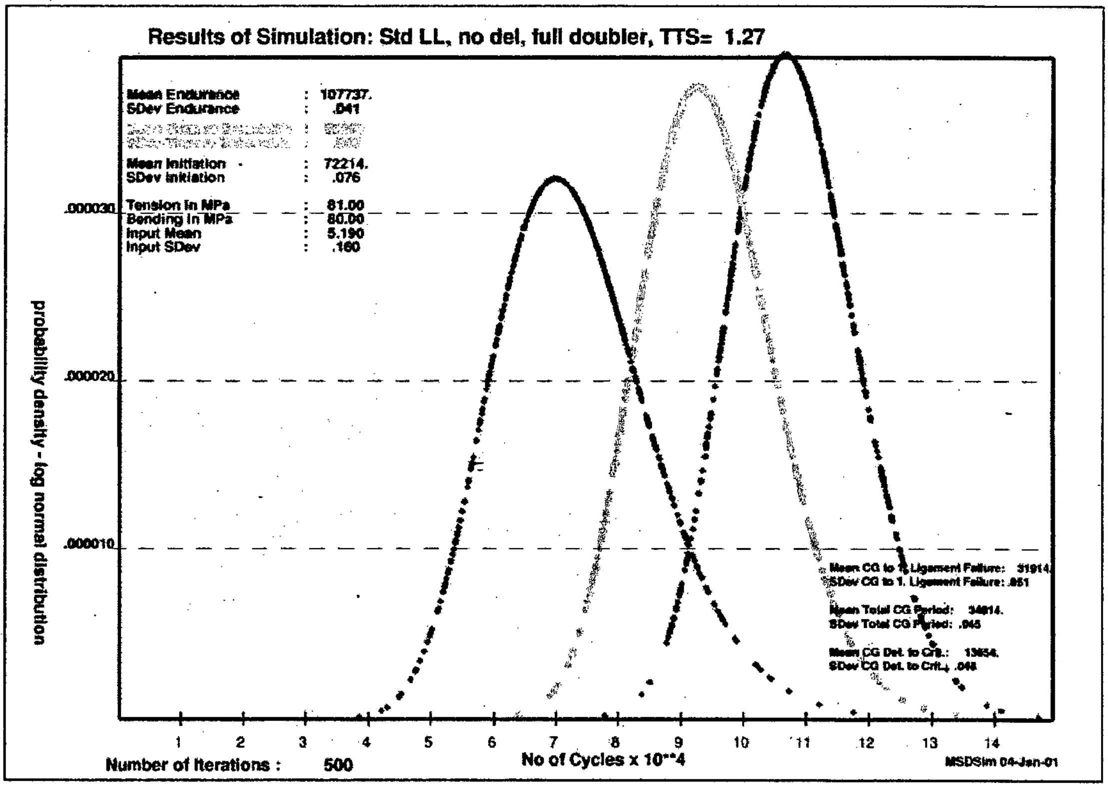

Figure 10 : Results of a complete Monte Carlo Simulation comprising 500 iterations

For relatively simple situations, such as constant amplitude cyclic loading, it is possible to evaluate rapidly many individual Monte Carlo scenarios with reasonable computational effort (of the order of 100 scenarios per minute on a UNIX workstation). To obtain stable results the number of Monte Carlo iterations performed should be in the order of 250 to 500 as illustrated in Figure 11. However, the incorporation of more complex features within the model, such as the calculation of crack growth under spectrum loading or the use of sophisticated techniques such as finite element modeling would require significantly more computation time and would therefore limit the number of scenarios. A careful balance between accuracy and speed needs to be achieved.

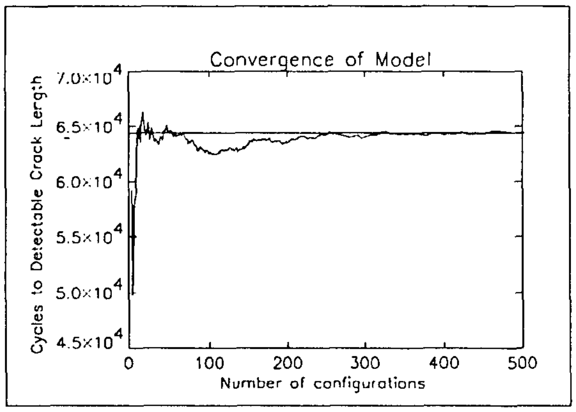

Figure 11 : Number of Monte Carlo iterations to obtain a stable mean value

The analysis tool (MSDSim) has been validated theoretically through comparison to existing fracture mechanics tools, such as NASGRO [5], FRAN2D [7][8][9], AFGROW [6], etc. An example is given in Figure 12 : Special emphasis has been given to the investigation of the crack interaction phenomenon. The stress intensity factors calculated for two approaching crack tips have been compared to the FRANC2D calculation to ensure accurate performance of the code.

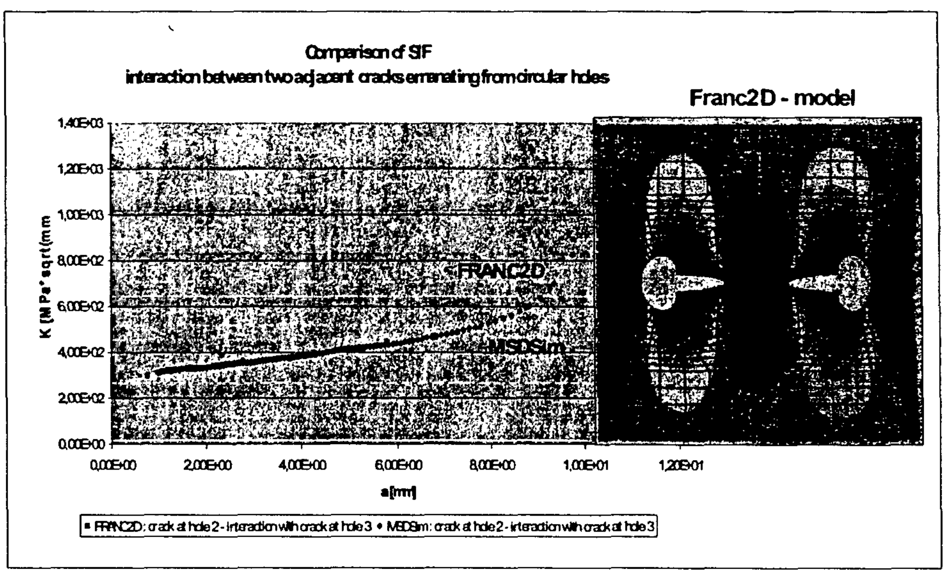

Figure 12 : Comparison of stress intensity factor calculation for two interacting cracks

Additionally, extensive comparisons to test results derived from the Airbus WFD Testing Programme as well as from Full Scale Fatigue tests have been done to validate the code on an experimental basis. The next chapter outlines details of this test programme and provides examples for the experimental validation.

WFD Testing Programme

Two general objectives are the background for the test programme performed by Airbus Deutschland GmbH:

1. provide a sound experimental basis for the WFD assessment and
2. to provide experimental data for the verification of the analysis tool described above.

The test programme is intended to cover the major structural areas of the A300 under responsibility of DA, which are potentially susceptible to Multiple Site Damage and subsequently to Widespread Fatigue Damage. Since longitudinal and circumferential joints have a high potential to develop MSD simply due to their large number of structural details operating at a similar stress levels, these areas form a large part of the WFD test programme. Another high priority MSD item is the rear pressure bulkhead skin.
Consequently, three major test batches covering different variations in geometry and conditions have been performed :

1. Longitudinal Lap Joints
   - Standard A300 lap joint
   - Standard A300 lap joint without doubler delamination
   - Lap joint variants
   - Panels from retired A/C
2. Circumferential Butt Joints
   - A300 circumferential joint
   - A300 Circumferential joint with doubler delaminated
   - New panels
3. Rear pressure bulkhead skin at splice of attachment angle

To fulfil the second general objective an additional batch comprising generic tests has been tested, tuned to investigate specific features of the analysis tool.

The detailed objectives of the test programme were :

- Evaluation of multiple crack propagation, i.e. MSD crack scenarios,
- Investigation of residual strength for different length of lead crack in combination with different MSD scenarios
- Investigation of the occurrence of WFD, i.e. the fatigue concept.

The crack propagation specimen contained artificial corner or through cracks of different lengths. The implementation of artificial cracks ensured that MSD scenarios were obtained, i.e. crack scenarios, where multiple cracks start growing, link up and finally cause failure, rather than local damage scenarios, where an isolated crack grows to failure.

In total 463 small (width 440mm) and large (width > 1000mm), unstiffened and stiffened coupons were tested and 4 curved panel tests were conducted.
The two longitudinal lap joint panels were cut from a retired aircraft, which had already accumulated 36 000 flight cycles. The panels were then tested for remaining fatigue life, crack growth and residual strength.
For the experimental validation of the analysis tool the majority of the coupon tests have been simulated analytically. Figure 13 provides an example of the comparison between calculation and test results. Shown is the crack propagation associated with each rivet hole in a joint containing a combination of 1.27 mm (0.05 inch) and 0.127 mm (0.005 inch) cracks.

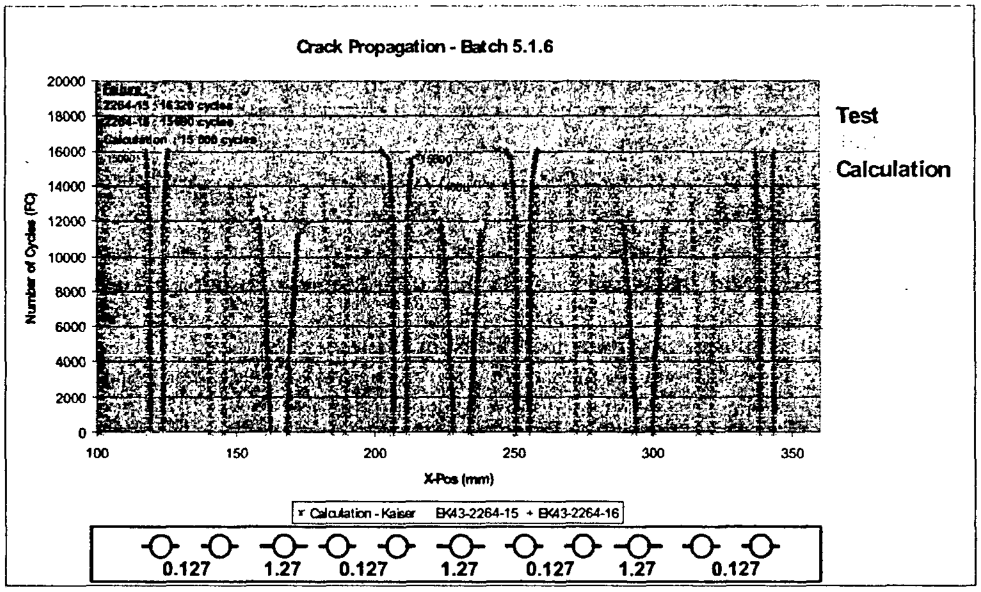

Figure 13 : Experimental validation of the analysis tool using data from the WFD Test Programme

The validation of the analysis tool included the growth and link-up of multiple cracks until specimen failure in complex structural items such as riveted joints. The comparison between test and analysis proved that the WFD analysis tool is able to simulate crack scenarios of varying complexity ranging from simple hole cracking to complex MSD crack scenarios at riveted joints. The analytical results were generally slightly conservative compared to the test results, as expected from any analysis tool. Furthermore, lap joint damages resulting from MSD crack initiation and propagation in A300 Full Scale Fatigue Test were successfully simulated.

Additional Programmes : Tear Down and Corrosion Prevention and Control Programme

A special activity under the Airbus A300 life extension programme is the tear down investigation of an old in-service aircraft. Airbus bought the airframe of the A300 MSN 008 which has accumulated approximately 75 percent of its DSG. The following investigations have been performed :

- Inspection and tear down investigation of areas potentially susceptible to WFD, especially longitudinal lap joints, circumferential joints, rear pressure bulkhead attachment to fuselage.
  - Inspection of 50 m longitudinal lap joint according to NTM
  - Inspection of special areas of long. lap joints with Rototest and Microfractographics
  - Inspection of rear pressure bulkhead according to NTM
  - Inspection of complete rivet row one of pressure bulkhead with Rototest
- Inspection and tear down investigation of areas where local damages (cracks) may occur.
- Inspection and tear down investigation of areas susceptible to corrosion.
- Crack growth testing of skin material to investigate possible material degradation : several structural parts will be tested to derive material data, especially da/dN and fracture toughness data, for comparison with former and actual material properties

Another important topic under the life extension activities is the prevention of corrosion in the ageing fleet. Therefore a Corrosion Prevention and Control Programme (CPCP) was established which is reviewed periodically.

Conclusion

Since an increasing number of Airbus A300 aircraft are approaching their original DSG or will reach their DSG in the near future, Airbus Industry has defined new ESG and launched a Full Life Extension Programme for the A300 models, i.e. A300B2, B4-100, B4-200 and B4-600. In order to justify a further period of operation up to the new ESG, it is necessary to review in-service experience and re-assess the existing inspection programmes. For pressurized fuselage, which is mainly under responsibility of Airbus Deutschland GmbH, this includes a complete fatigue and damage tolerance analysis of the original structure, modifications and repairs, which may lead to a modification of the maintenance strategy, including the inspection of additional items or an increased level of surveillance in some areas.
In order to ensure compliance with the new requirements, which concern the need to limit the validity of the current structural maintenance programme and the need to impose operational requirements that mandate a structural maintenance programme to prevent Widespread Fatigue Damage in the fleet, special emphasis is given to the analysis of MSD and MED, which are both defined as sources of WFD.
A new analysis tool was developed to assess structural items potentially susceptible to WFD and a large Widespread Fatigue Damage Test Programme, including 463 small and large coupon tests and 4 large curved panel tests, was conducted. Special inspections tuned to MSD/MED will be established between the Inspection Start Point (ISP) and the Structural Modification Point (SMP), the point beyond which the aircraft may not be operated without further evaluation or modification. The calculation of these points and the inspection interval is done by means of a Monte-Carlo simulation to reflect the statistical/probabilistic nature of MSD, where multiple initial crack scenarios are randomly generated and for each scenario subsequent crack propagation and failure is calculated.
Significant effort was undertaken to develop and validate the computational tool for the Monte Carlo simulation with special consideration of balancing the needed accuracy against the speed of complex calculations.

The large number of activities undertaken to obtain the goal for the A300 Life Extension Programme may be summarized as follows :

- Evaluation of structure potentially susceptible to local damage
  - Evaluation of in-service and Full Scale Fatigue Test Experience
  - Tests for areas susceptible to local damage
  - Conventional fatigue and damage tolerance analysis
- Evaluation of structure potentially susceptible to MSD/MED
  - Evaluation of in-service and Full Scale Fatigue Test Experience
  - WFD testing
  - Development of MSD/MED analysis tool
  - Validation of analysis tool
  - Complex MSD/MED analysis
- Tear Down investigation of a retired aircraft
- Evaluation of repairs, in-service problems and Structural Repair Manual
- Definition of new inspection programmes, adjustment of existing inspection programmes
- Definition of modifications

Figure 14 presents the distribution of financial effort spent for the major Full Life Extension activities (evaluation of repairs and definition of modifications not included).
Approximately 30% of the total effort was required for the evaluation of local damage (including local damage testing), while tear down and definition of inspection programmes only make up a small part of the total amount. It becomes obvious that the largest portion, almost 70% of the total effort, is assign to the evaluation of WFD with approximately half of that amount being consumed by WFD testing. However, 15% of the total amount was required for the development and validation of the analysis tool – this amount would not be counted for any follow-up life extension programme, e.g. for A310, A320 models. Furthermore, a large portion of the WFD testing was conducted in order to obtain

data for the validation of the analysis tool, which would not be necessary for future projects, and large datasets are applicable to other Airbus aircraft.
Consequently, as shown in **Figure 15** for future life extension projects the effort assigned to WFD analysis would be significantly reduced (roughly in the order of 40%).

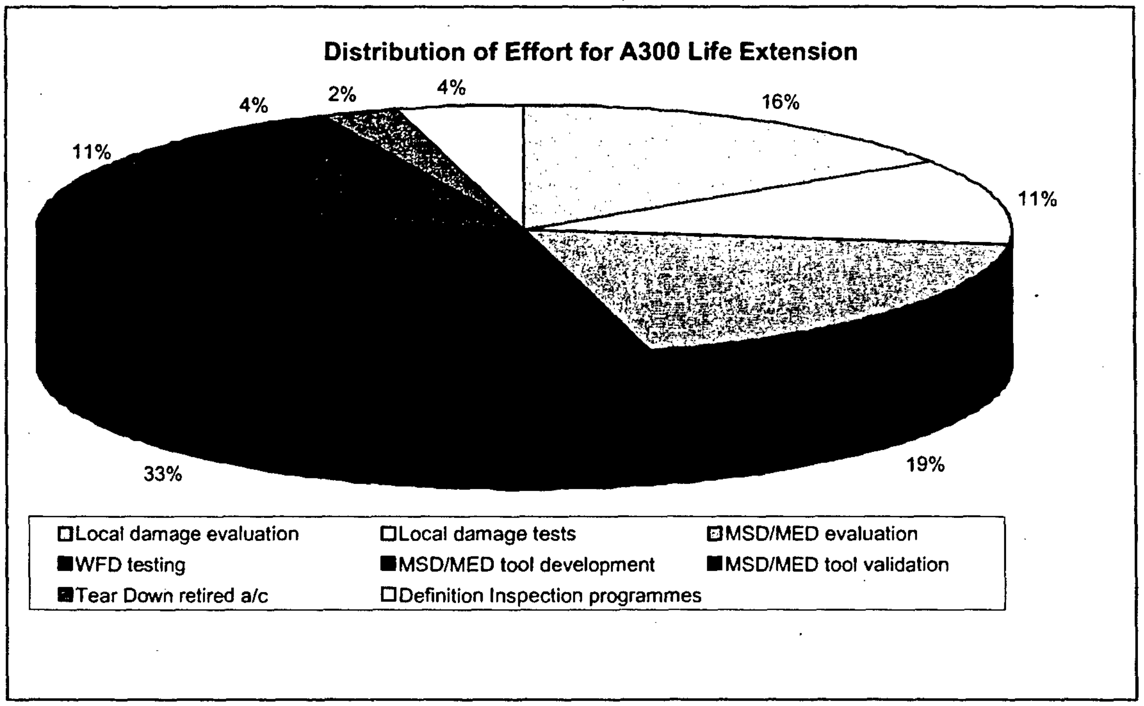

Figure 14 : Distribution of Financial Effort for A300 Life Extension (on man-months basis)

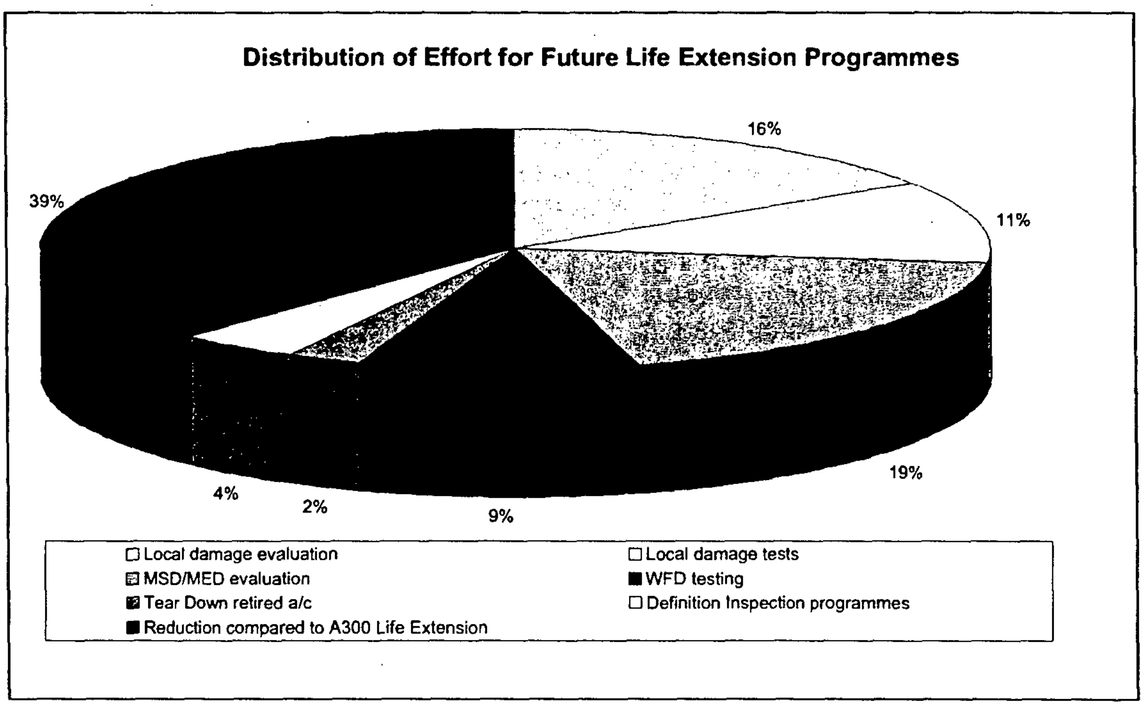

Figure 15 : Distribution of Financial Effort for Future Life Extension Programmes

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